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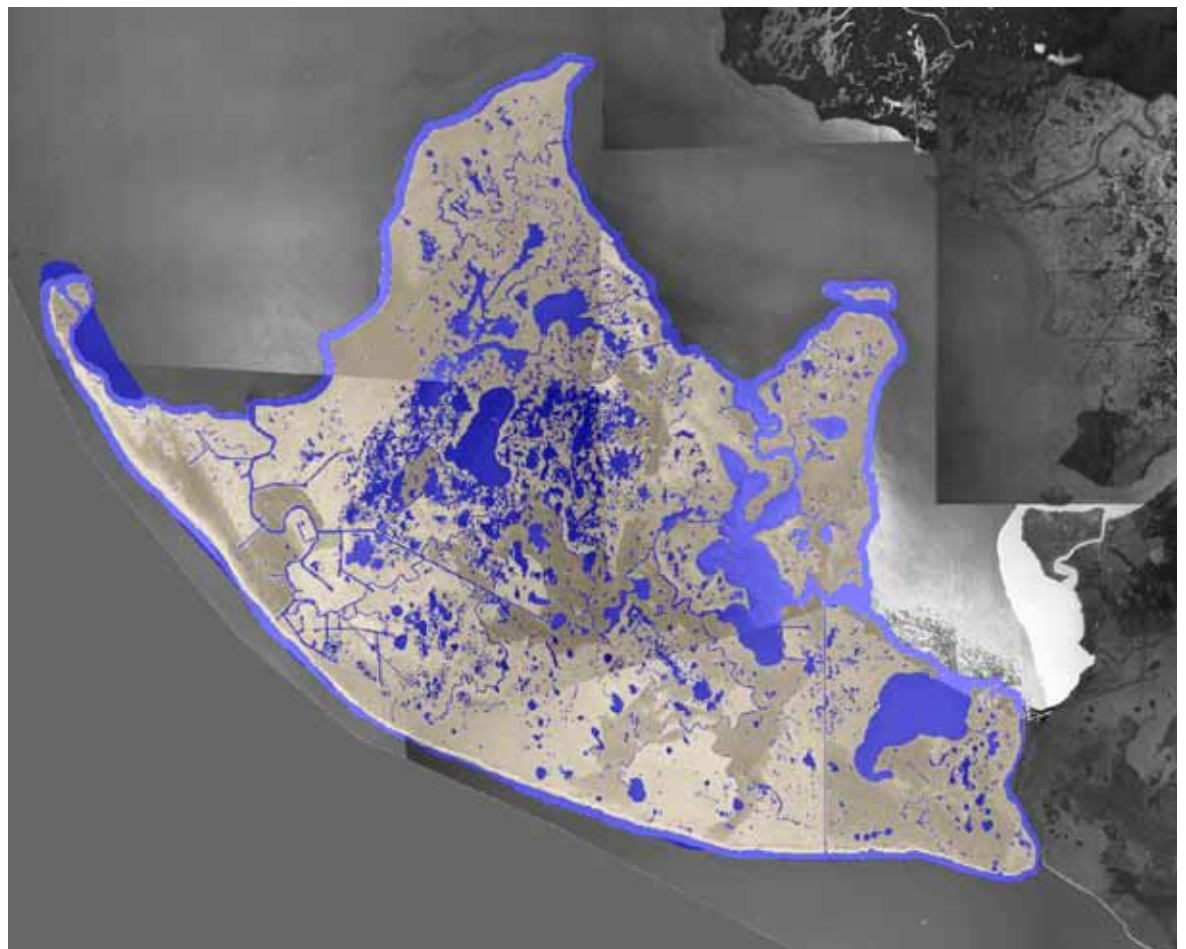
System-Wide Water Resources Program

Development of Methodology to Classify Historical Panchromatic Aerial Photography

Analysis of Landscape Features on Point Au Fer Island, Louisiana - from 1956 to
2009: A Case Study

Glenn M. Suir, Christina L. Saltus, James B. Johnston,
and John A. Barras

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Final report

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Abstract: Recent studies of coastal Louisiana landscapes have shown an increased connection between historical episodic events and current landscape condition. Therefore, the importance of historical landscape reconstruction through the interpretation of panchromatic aerial photography has increased because it provides synoptic views of hydrology, vegetation, and ecosystems for time periods when data options are limited. Though panchromatic aerial photographs provide a valuable historical record of past landscape conditions, their use is limited in current landscape analyses due to issues with established automated techniques to classify these data (e.g. only one gray level band, and illumination inconsistencies), and the subjectivity and time-intensive nature of human-derived photo-interpretation products. This report documents a method that was developed to improve panchromatic aerial photography classification by increasing accuracy and control and reducing the time-intensive nature of this technique. This method provides a novel approach to selecting landscape features based on a specific range of pixel values (color), contrast, texture, and pattern within a single gray level band of source photography. The resulting techniques were evaluated and used to classify and assess historical land and shoreline change at Point Au Fer Island (PAFI), Louisiana. Assessments show that though this method is more time-intensive than the automated classification approaches used with color-infrared and multispectral data, it provides many advantages over previous panchromatic aerial photography classification methods. These advantages include the use of image level, contrast, and color adjustments; tools to rapidly select features of similar characteristics; and adjustment layers to enhance the visual identification of the land-water features and interface.

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Preface

The research documented in this report was conducted as part of the System-Wide Water Resources Program (SWWRP). The SWWRP is sponsored by Headquarters, U.S. Army Corps of Engineers, and is assigned to the U.S. Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL) and the Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS. The SWWRP Program Manager is Dr. Steven Ashby.

This report was prepared by Glenn Suir, Christina Saltus, and James Johnston, Environmental Systems Branch (EE-C), ERDC-EL and John Barras, U.S. Geological Survey, Eastern Geographic Science Center – Baton Rouge Colocation Office. The report was prepared under the general supervision of Mark Graves, Chief, EE-C; Dr. Edmond J. Russo, Jr., P.E., Chief, Ecosystem Evaluation and Engineering Division, EL; Dr. Jack Davis, Deputy Director, EL; and Dr. Beth Fleming, Director, EL.

COL Kevin J. Wilson was Commander of ERDC. Dr. Jeffery P. Holland was Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
miles (U.S. statute)	1,609.347	meters
square miles	2.589998 E+06	square meters

1 Introduction

1.1 Wetlands

Wetland communities perform many important functions and are as productive and vital an ecosystem as any other on Earth (Patrick 1994). These landscapes - with their unique physical, chemical, and biological processes - create dynamic environments that provide protection from storms; serve as species habitat; act as a control for nutrient and pollution transfer; support fish, agriculture, wildlife, and wood production; and through accretion processes – provide a natural counter to sea-level rise (Lehtinen et al. 1999; Barbier 1994; Cahoon and Lynch 1997).

Louisiana consists of approximately 30% (13,600 km²) of all coastal wetlands located in the lower 48 states, but has accounted for 90% (4,700 km²) of all coastal marsh loss since the 1930s. These coastal Louisiana losses — which operate on varied time scales, and as a result of both natural and man-induced events — jeopardize the nation's most productive estuaries, largest coastal channel water-borne commerce, and most critical oil and gas infrastructure (U.S. Army Corps of Engineers (USACE) 2004; Louisiana Department of Natural Resources (LDNR) 1997 and 2007). In order to impede these losses and thereby conserve the biological diversity, spatial integrity, economic value, and overall benefit associated with these landscapes, it is imperative that the measure and comprehension of long- and short-term wetland ecosystem structure, function, and change are advanced (Forman 1995).

1.2 Wetland assessments

Wetland assessments provide resource managers and stakeholders with valuable information related to the distribution and condition (past, present, and future) of wetland landscapes, and assist in the management and fate of these natural resources (U.S. Fish and Wildlife Service (USFWS) 2009). Quantifying the change (magnitude and sequencing) and trends in wetland composition and configuration provide measures of wetland conditions, stability and corresponding wetland functions, benefits, and services, and coastal wetland resilience. The potential for quantifying those structural components, identifying ecologically important landscape characteristics, and assessing their linkages to ecosystem function is

increased through the integration of photo interpretation and remote sensing techniques (Yang and Liu 2005).

Landscape assessments of coastal Louisiana have evolved from on-site evaluations and composition analyses (O'Neil 1949, Gagliano and van Beek 1970, Chabreck 1972) to more complex rates of change and sequencing measurements through the interpretation and processing of recent aerial photography and digital imagery (Barras et al. 2003, Bernier et al. 2006). However, to better understand deltaic and wetland processes, future assessments must transcend short-term baseline composition and change, and also consider the long-term effects of historical episodic events on landscape function and stability.

1.3 Wetland mapping methodology

Wetland classification and mapping are key components in the inventory, assessment, and monitoring of Louisiana's wetland resources. Wetland classifications have been performed using three primary methods: (1) field observations, (2) manual interpretation and classification of aerial photography, and (3) automated classification of air- and space-borne imagery. When feasible, all classification methods should utilize training sites and ground-truthing techniques to maximize classification accuracy.

O'Neil (1949) assembled one of the first wetland classification datasets in Louisiana. The data were collected via visual field observations (north-south transects) and through interviews with land managers and trappers of coastal Louisiana (U.S. Geological Survey (USGS) 2000). Since the 1949 survey, six coast-wide visual field observation surveys (1968, 1979, 1988, 1997, 2001, and 2007) were performed in an effort to update the existing Louisiana coastal marsh-vegetative type data (Chabreck et al. 2001, Sasser et al. 2008).

Historical wetland assessments have also been performed as habitat or land-water analyses through manual classification of panchromatic (black and white) and color infrared aerial photography. Landscape features are typically based on photo radiance, contrast, texture, and pattern recognition, and classified using either a manual interpretation with digital transfer or through on-screen interactive "heads-up" techniques. Photographic coverage for these classifications consists of panchromatic photography and large-scale color infrared aerial photographs that exist as controlled frames or mosaics (Wicker 1980). One of the earliest coast-wide wetland

classifications was conducted using the 1930s U.S. Coast and Geodetic Survey Air Photo Compilation Sheets (T-sheets). The 1930s T-sheets are the oldest photo-based data with suitable coverage and a level of detail that is adequate for land-water classification. The resulting 1930s land-water data have served as the baseline for most historical land change assessments in coastal Louisiana (Britsch and Kemp 1990). Another widely used data set that was derived from large-scale panchromatic aerial photography is the modified 1956 habitat data. The 1956 photos were digitized and manually classified to the National Wetland Inventory (NWI) standard using the Cowardin et al. (1979) wetland classification scheme (USGS 1997). These data are commonly used for wetland value and land change assessments (Saltus et al., in preparation) within ecosystem restoration planning.

Recent wetland classifications have relied on color-infrared aerial photography, Landsat Multispectral Scanner (MSS), and Thematic Mapper (TM) satellite imagery to classify landscape features (Folse et al. 2008; Couvillion et al. 2011). These higher temporal and moderate spatial resolution data are best suited for quantifying larger landscape features and areas of rapid land change. The automated classification processes that are typically used with these data incorporate unsupervised classification techniques to specify parameters by which statistical patterns are analyzed and clustered according to minimum spectral distances. Additionally, the high absorption of the mid-infrared portion of the spectrum by water, and the high reflectance by vegetation, provide additional means of discriminating land from water and automating the classification process (Braud and Feng 1998).

1.4 Historical landscape reconstruction

Recent studies have shown an increased connection between historical episodic events and current landscape condition (Morton et al. 2005; Barras et al. 2008; Morton and Barras, in preparation; Saltus et al., in preparation). Therefore, the importance of historical landscape reconstruction through the interpretation of panchromatic aerial photography has increased because it provides synoptic views of hydrology, vegetation, and ecosystems for time periods when data options are limited (Harvey and Hill 2001). Though panchromatic aerial photographs provide a valuable historical record of past landscape conditions, complications with using established automated techniques to classify these data (e.g. only one gray level band, and illumination inconsistencies), and the subjectivity and time-intensive nature of human-derived photo-interpretation products, are issues that limit their use in current landscape analyses (Carmel and

Kadmon 1998, Finlayson and van der Valk 1995). Figure 1 illustrates the level band and illumination inconsistency issues that plague both the automated and manual approaches to classifying panchromatic photography. The purpose of this report is to describe a method that was developed to increase the accuracy and control, and reduce the time-intensive nature of panchromatic aerial photography classification. The resulting techniques were evaluated and used to classify and assess historical land and shoreline change. These change data were subsequently used in the development of restoration plans for the Louisiana Coastal Area (LCA) Ecosystem Restoration Program's Mississippi River Gulf Outlet Canal Environmental Restoration project (Saltus et al., in preparation), Gulf Shoreline at Point Au Fer Island (PAFI) project, the Land Bridge between Cailliou Lake and the Gulf of Mexico project, and review of the West Bay Sediment Diversion project (Barras et al. 2009). The project history, analyses, and output for the Gulf Shoreline at PAFI are provided in Appendix A as a case study of the application and usefulness of the method described herein.

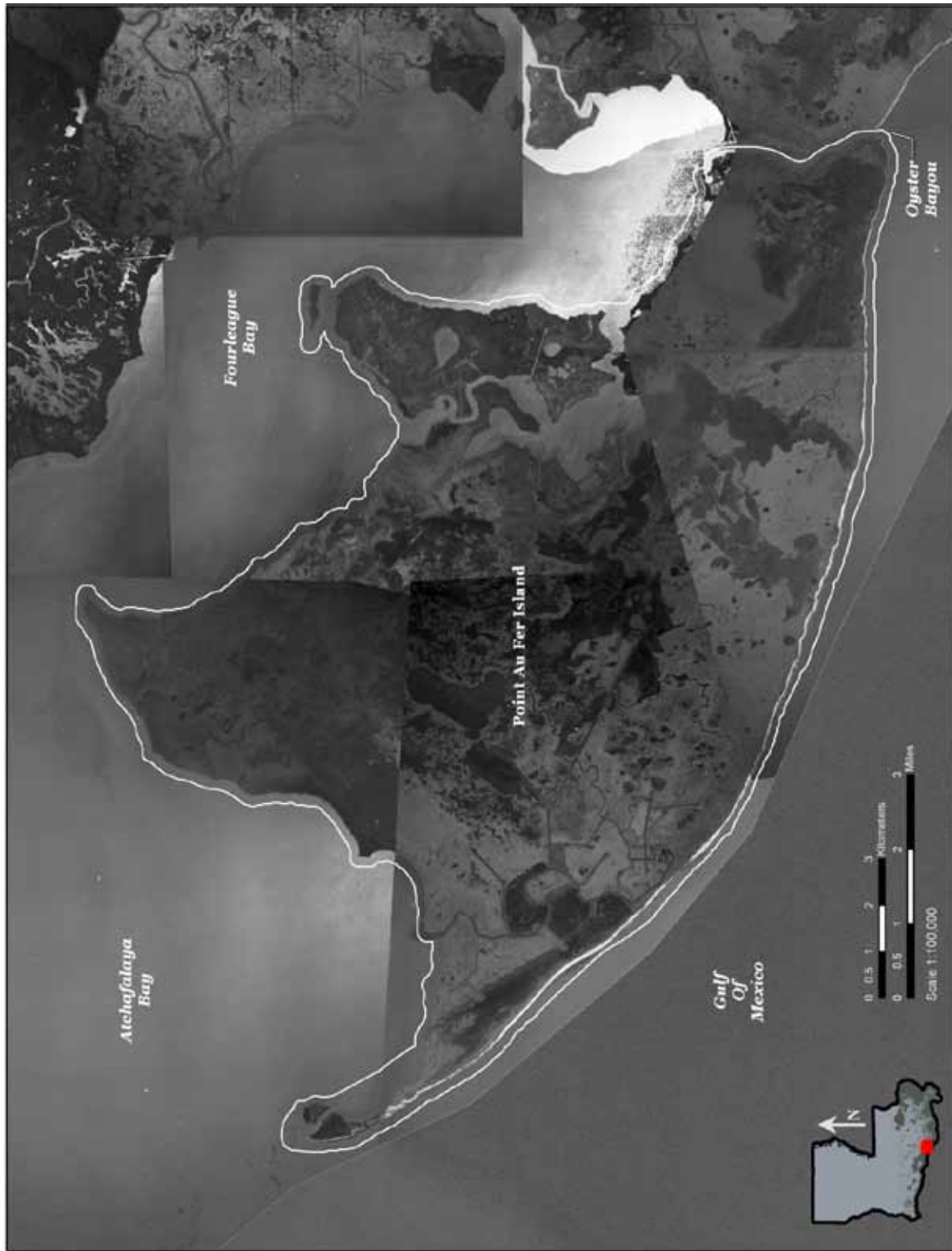


Figure 1. 1965 panchromatic aerial photographs illustrating illumination and tonal inconsistencies for the area within Point Au Fer Island, Louisiana.

2 Methods

This report provides the rationale for and a step-by-step guide to a novel method for classifying panchromatic aerial photography.

2.1 Acquisition of source photography

The first step in classifying panchromatic aerial photography is the acquisition of the data. Historical panchromatic photography can be obtained from a myriad of sources and in a number of formats. Typical sources include government agencies and programs, universities and other institutional cartographic libraries, and commercial photography and mapping service companies. Most existing historical panchromatic photos exist as individual frames from print or film. These frames should be scanned (digitized) and saved in a high quality digital format - preferably as a 1200 dots per inch (dpi; minimum 600 dpi), 8-bit (can be 16-bit) grayscale Tagged Image File (TIF).

2.2 Pre-processing of source photography

The pre-processing of source photography consists of (but is not limited to) digitizing, resampling, subsetting, rectifying, reprojecting, and mosaicking all frames within the project area. Several commercial geographic information system (GIS) software packages are useful for photograph pre-processing. These include ERDAS Imagine (ERDAS Inc., Norcross, Ga.), Avenza Geographic Imager (Avenza Systems Inc., Toronto, Ontario, Canada) for Adobe Photoshop (Adobe Inc., San Jose, Ca.), ESRI ArcGIS (Environmental Systems Research Institute, Redlands, Ca.), and others.¹ Some software packages perform specific operations better than others; therefore, it is not uncommon to use these applications in conjunction with each other. ERDAS Imagine and Adobe Photoshop were the software applications selected for use in this effort. ERDAS Imagine offers traditional photo pre-processing tools and Adobe Photoshop provides unique photo editing and manipulation capabilities.

¹ Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Modern digital photography is generally color and contrast balanced across all frames or tiles (ex. Digital Orthophoto Quarter Quadrangles). However, variations within and across historical panchromatic photography often necessitate data enhancements (e.g. contrast, level, exposure; Figure 1) for more accurate visual interpretation and land-water classification. Also, source panchromatic photography often consists of varying scales, resolution, and print size. Therefore the photos must be resampled, rectified, and mosaicked within a projection system that suits the project extent, location, and intended analyses. Overlaying and adjusting various frames within a mosaic offers tradeoffs on rectification accuracy and image quality. The goal is to create a base mosaic that enhances the classifying process while providing the maximum visual contrast and interpretability. It is highly recommended that a bounding area be delineated and used to subset and classify the source panchromatic photography to the limit of the minimum project area where feasible to minimize classification-matching issues across multiple images. It is also recommended that a world file [e.g. tif world file (.tfw)] with projection information be created (or ensure that one exists) and that the extent of the mosaicked photography is not manipulated by image cropping or pixel resampling. This ensures consistent projection and coordinated information between software packages.

2.3 Water classification

The core of this method is the use of selection tools to delineate all identifiable water features within the base panchromatic photo, and to classify/symbolize those areas in a separate layer. Since the file exists as an 8-bit gray scale image, and the objective is to color-code all land and water features, it is useful to convert the file to an RGB (red-green-blue) 8-bit color image. Using Adobe Photoshop, open the pre-processed mosaicked TIF image and convert the file by selecting RGB Color and then 8 Bits/Channel options under the Image > Mode menu. Converting the source image from an 8-bit gray-scale format to a 24-bit color format will triple the size of the file. Photoshop requires large amounts of RAM (> 3 GB) to efficiently handle the water classification process when using high-resolution panchromatic photography. Large areas may require tiling to reduce image size to improve image classification and processing efficiency within Photoshop. The classified water images derived from the image tiles are converted to a 4-bit color image, decreasing file size to 17% of the source 24-bit file. The classified tiled images are then mosaicked using GIS software to form seamless coverage of the project area.

The water classification process consists of selecting water features from the source panchromatic image layer and creating a separate "water" layer using the following procedure.

- Create a new layer, name it "Water," assign the color blue for easy recognition, and save the file as a working copy in either TIF or Photoshop format.
- Select the "Magic Wand" tool from the Photoshop tools palette.
- From the options bar, un-check the Anti-alias box, check the Contiguous box, and make sure that the tool's tolerance is set to a value that ranges from 6-10.

The tolerance setting that sets the range of pixels to be selected is variable and dependent on image tonal quality, and therefore may require adjustments to maximize feature selection. Anti-aliasing generates soft edges, but since the final classification will consist of two distinct classes, sharp edges are preferred. Since illumination and tonal inconsistencies are common with panchromatic photography, using the Contiguous setting will limit the working selection to adjoining pixels of similar brightness values. This allows for increased control over feature selection. If preferred, the "water" fill can be applied to a gray scale image, but it will appear as a shade of gray within the water layer and may cause confusion with the underlying base layer.

Ensure that the base photo layer is active (active layers are those that are highlighted in the Layers Palette) using the following procedure:

- Activate a layer by clicking on the layer name in the Layers Palette.
- Pan and zoom to a large water feature and click within it using the Magic Wand tool. Based on the tolerance setting, the Magic Wand will select all pixels that fall within a specific range of the pixel value (color or grayscale) that was selected.
- Holding the shift key and continuing to click additional water areas bordering the initial selection will append the previous selection. Conversely, holding the option key and clicking allows for the removal of non-water areas from the working selection.

The Magic Wand provides a tool for general selection, and though this tool may suffice for some projects or areas, refinements to the selection may be necessary and accomplished using other options and/or selection tools. The

Refine Edge options allow for improved accuracy of the feature selection. Radius, Contrast, and Contract/Expand are Refine Edge options that allow for more exact selection boundaries through increasing selection radii, sharpening selection edges, and contracting/expanding the selection boundary. The Lasso tool allows for manual tracing of features, which through the use of the shift- or option- key, can be used to add/remove areas from the working selection. Another selection tool, the Magnetic Lasso Tool, uses differences in brightness values to identify and snap the selection boundary along the edges of a feature.

Once a water feature selection(s) has been finalized, ensure the Water layer is active, and select an appropriate water classification color using the Color Picker (Foreground) tool from the Tools Palette. A shade of blue is the obvious and simple choice, but it can be changed to a preferred color once all land and water features have been classified. From the Tools Palette, select the Paint Bucket Tool and click inside the working selection boundary to fill the feature with the designated water classification color.

Toggling the Water layer on and off during the classification process will aid in the selection of water areas and allow for increased accuracy of the classified image. It is common to inadvertently fill selected areas in the base image layer instead of the Water layer, or even delete entire working selections from the base image. If not corrected, these mistakes will permanently obscure the source background image. Ways to minimize these errors are to be cognizant of them (frequent toggling), use the Undo or Step Back features, and create complete image backups (important since a week's worth of work can be lost by an accidental "fill"). Continue the selection and filling process until all project area water features have been classified.

2.4 Land and water classified image

At this point the classified water layer contains "noise," randomly distributed pixels or color levels of water. Applying a Noise filter will reduce this noise by altering or removing pixels of a given size or distribution. First, right-click the Water layer in the Layer Palette, select Duplicate Layer, name it Smoothed Land-Water, and click OK. Next, select the Median option from the Filter > Noise menu. Set the pixel Radius to 1 (this may vary, depending on the imagery source resolution and photo-scale) with the preview option checked and click OK. This process smoothes the layer by eliminating all one-pixel speckling from the water classification. If additional noise is

present, repeat this process and increase the Radius value until the filtering is acceptable.

Using the Magic Wand with Contiguous un-checked, select a large water feature from the Smoothed Land-Water layer. Notice that not all water areas are selected. The filling process in RGB 8 bit mode uses anti-aliasing and various shades of the color are used to identify the water features in the image. One solution is to select all of the water and refill with a standard color. This approach eliminates some of the subtle RGB 8-bit water color variations that will prove problematic when converting to an 8-bit indexed color thematic image. Use the Select > Similar tool to select all water, fill the selection with an appropriate water color, and save.

The land classification is generated by using an inverse selection of the water within the Smoothed Land-Water layer. Use the same process to again select all water within the Smoothed Land-Water layer. Then use the Select > Inverse option to select all non-water or land area, fill with an appropriate land color, and save. It is recommended that a complete image backup be created at this time.

To further reduce the amount of color variation in the image, a conversion to 8-bit indexed Color is used. This process creates a panel by sampling the colors from the spectrum appearing most often in the image. For example, an RGB image with only the colors green and blue produces a panel made primarily of greens and blues. To control a panel more precisely, the user has the ability to select colors of emphasis, and/or the number of classes in the output. Photoshop weights the conversion towards these options. This method uses three colors, one for land, one for water, and one for the background. Since this method only works on single layer (or flattened) images, select all layers other than the Smoothed Land-Water layer and delete them. From the Image > Mode menu, select Indexed Color. From the Indexed Color window, select Palette = Local (Adaptive); Colors = 3; Forced = None; Matte = None; Dither = None. The resulting image now contains only three colors. When the file is later imported into ERDAS Imagine (for Summary and Trends analyses) a recode will be required, but it is only for the minimum number of classes/colors. Perform any additional editing (i.e. remove remaining noise or speckling, etc.), and save the file as a color-indexed TIF.

2.5 Summary, trends, and change pre-processing

Summary, trends, and change analyses of land-water and habitat data provide key knowledge elements that allow for inventorying and monitoring of natural resources, forecasting of resource condition and stability, and tools necessary to formulate and implement restoration strategies. To begin the summary and trends processes, convert the TIF file to the Imagine format by importing the file into ERDAS Imagine using the Import/Export TIF dialog. To ensure that the classification and conversions were performed correctly, display the image in Imagine, and review for errors or inconsistencies. Recoding of the land, water, and background classes may be required to standardize the thematic classification with existing thematic land-water datasets. Since resizing of the image was not performed through the classification process, the use of the original pre-processed image source world file provides a method for assigning geocoding information to the Imagine file. Select the Image Info button > Edit > Change Map Model, transcribe the coordinate information from the world file (.tfw), and select the appropriate unit and projection. Use Recode to convert the file to a standard Imagine 4-bit thematic land-water file. Assign appropriate colors and class names to the recoded file. The result should be a standard land-water file for the project area derived from the source historical aerial photography.

The resulting large-scale classified image can be used to compare land and shoreline change to other existing high- or moderate-resolution archived data for statistical trend analyses. Pixel resampling is required to consistently compare the classified high-resolution classified panchromatic photography (1 m to 3 m) with moderate resolution (25 m to 30 m) data sets. Reproject the file in Imagine using Data Preparation > Reproject Images. Resample the image from the source resolution to one matching those of the archived data. Assign the output projection that matches the input (or matching those of the archived data).

To remove remnant noise from the resampled file (this can also be done for the higher resolution image) the Clump and Eliminate procedure is performed. Run the Clump function from the Image Interpreter > GIS Analysis menu. A standard file-naming convention is to append the filename with the designation "_c" to signify the Clump function has been performed. To remove the noise from the clumped file, run the Eliminate function from the Image Interpreter > GIS Analysis menu. Use the default settings to eliminate one pixel speckling, and append the filename with an

"e" (_ce) to signify that the Eliminate function has been performed. The end result is a file compatible with archived data and suitable for running statistical trends, performing change analyses, or for creating spatial trends maps.

3 Conclusions

Historical aerial photography provides exclusive synoptic views of landscape and ecosystem features. However, complications in using established automated techniques to classify these data, and the subjectivity and time-intensive nature of human-derived photo-interpretation products, are issues that limit their use in current landscape analyses. With recent preliminary studies showing an increased connection between historical episodic events and current landscape conditions, a rapid and accurate method for classifying panchromatic photography is essential.

The method described in this document provides a novel approach to selecting landscape features based on a specific range of pixel values for color, contrast, texture, and pattern within a single gray level band of source photography. The development and modification of this method transpired over the course of several studies and evolved from a necessity to quickly and accurately classify historical panchromatic photography in order to identify storm-induced land loss and impacts (Morton et al. 2005; Barras et al. 2009; Morton and Barras, in preparation; Saltus et al., in preparation). Assessments show that though this method contains more uncertainty and interpreter error, and is more time-intensive than the automated classification approaches used with color-infrared and multispectral data, it provides many advantages over previous land and water classification methods that use panchromatic aerial photography. These advantages include the use of image level, contrast, and color adjustments; tools to rapidly select features of similar characteristics; and adjustment layers to enhance the visual identification of the land-water features and interface. However, given the age and quality of most historical panchromatic photography, the uncertainty and error associated with this method are typically interpreter-based and are often difficult to quantify.

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Appendix A: Analysis of Landscape Features on Point Au Fer Island, Louisiana - from 1956 to 2009: A Case Study

A.1 Background

Given the magnitude of Louisiana's coastal land losses and landscape degradation, the Louisiana Coastal Area Ecosystem Restoration Study (LCA Study) was authorized to restore the natural geomorphic structures and processes associated with 10 areas of concern (USACE 2004). One critical area, the Point Au Fer Island (PAFI) project area, is located 30 miles south of Morgan City, Louisiana, and is bounded by Oyster Bayou to the east, the Gulf of Mexico (GOM) to the south, Atchafalaya Bay to the northwest, and Fourleague Bay to the northeast (Figure A1). PAFI, which is approximately 17 miles in length and consists of 30,000 acres of non-fresh marshes, has experienced significant habitat loss due to human-induced hydrological conditions, shoreline erosion, and subsequent breaching and weakening in areas near man-made canals. To combat these issues, the LCA Study has established planning objectives to maintain PAFI by restoring inland marsh habitat, increasing the resistance to shoreline retreat via shoreline stabilization measures, and preventing direct connections between the GOM and interior water bodies (USACE 2010).

An in-depth knowledge of recent and historical coastal landscape history is one of the key elements required by project managers to make informed, reasoned decisions for implementing the overall LCA restoration strategy. The historical analysis and interpretation as part of this effort provide vital information related to the cause, extent, and timing of landscape and shoreline change. The following is a summary of historical and recent land, habitat, and shoreline changes within the PAFI project area.

A.2 Introduction

The current Louisiana coastal landscape is the result of natural and man-induced changes operating on varied time scales. Recent restoration efforts have attempted to assess these changes through the use of moderate resolution data. From 1983 through the present, Landsat TM satellite imagery has provided a same area return frequency of 16 days. The higher

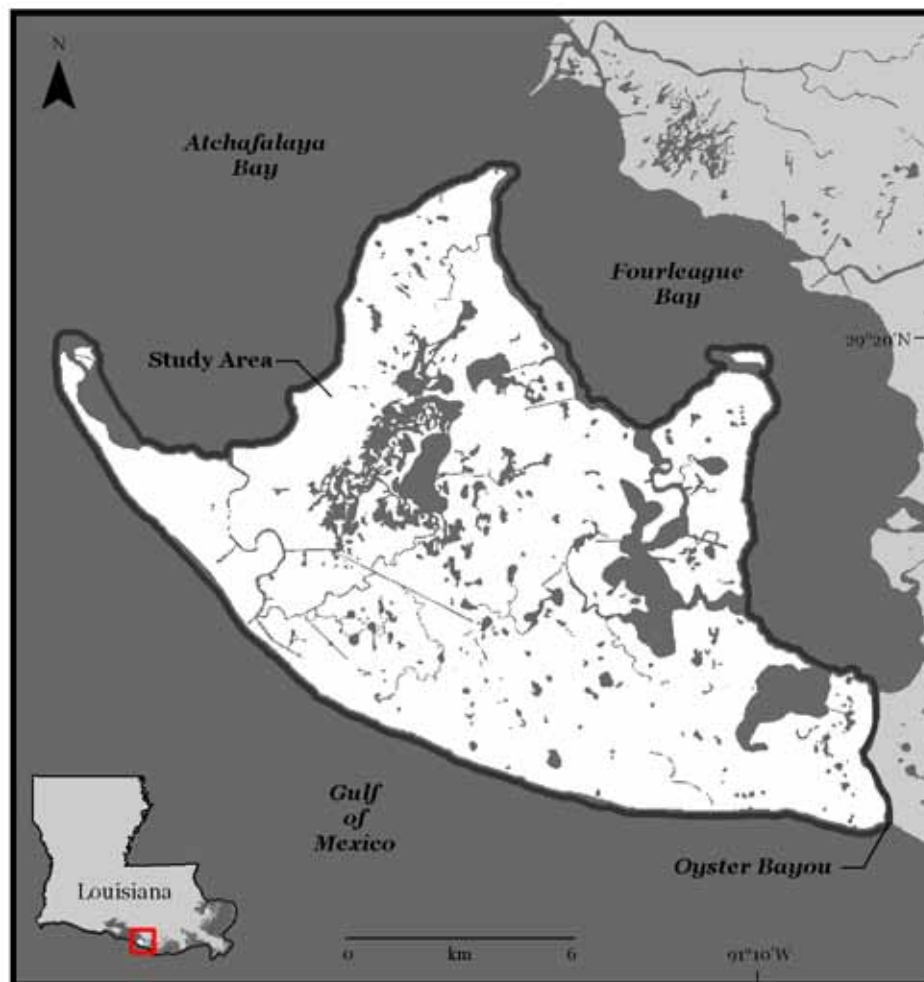


Figure A1. Point Au Fer Island location map.

temporal frequency and greater spectral resolution of this imagery is useful for estimating short-term land area variation linked to hurricane-induced episodic loss and/or prevailing environmental conditions (Barras 2006, 2007; Barras et al. 2010). However, recent land loss research has found that historical episodic events (those pre-dating 1983) may contribute more to recent coastal landscape history than previously thought (Barras 2006, 2009; Barras et al. 2008; Morton et al. 2005; Morton and Barras, in preparation; and Saltus et al., in preparation). Assessing historical land change trends within PAFI before 1983 (prior to Landsat TM satellite imagery collection), and linking those changes to specific episodic events, may not be possible without examining panchromatic photography that brackets those events.

Misinterpretation of the possible causes of localized loss linked to episodic events, based on decadal or longer comparison periods and method limita-

tions, may lead to the recommendation and application of inappropriate or ineffective restoration solutions. Therefore, the quantification of these event-induced changes requires the development of a classification method that reduces the limitations of previous methods (see method development details above). The novel photo-interpretation approach developed as part of this study was used to increase temporal frequency, which in turn provides a clearer understanding of land area change timing and magnitude within key restoration areas.

The purpose of this case study is to provide a refined landscape history for PAFI that both exceeds and supplements information provided by existing coastal habitat and land loss data sets. Examination of historical aerial photography, acquired from the 1950s through the 1970s, provides a means of identifying and empirically documenting the landscape changes attributable to episodic events. A refined loss history for PAFI - one that couples loss from episodic events or processes with current high temporal frequency assessments of the modern coastal landscape (Barras et al. 2008, Barras 2009) - provides reliable recent landscape evolution information over a period of analysis (50 years) that is adequate for project planning and implementation.

Land change trends discussed in this report were calculated using land-water data sets developed for prior coastal land area change assessments (Cahoon and Groat 1990; Barras et al. 1994, 2003, 2008; Barras 2006, 2009), as well as newly created land-water data sets. These data sets were derived from (1) Landsat Thematic Mapper (TM) satellite imagery obtained from the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS), (2) modified photo-interpreted National Wetlands Inventory (NWI) habitat data, and (3) land-water data sets photo-interpreted from panchromatic and color infrared (CIR) aerial photography.

A.3 Methods

This case study identifies and quantifies historical (1956-1978) and recent (1983-2009) land, habitat, and shoreline change within PAFI, and evaluates correlations between these changes and soil mapping units. The assessments performed as part of this study are based on representative land-water, habitat, and soils data from the 1956 to 2009 period of analysis.

The PAFI land area changes were analyzed using a sequential series of 29 land-water data sets obtained from 1956 to 2009. The historical period

of analysis consists of three dates; 1956, 1965, and 1978. The 1956 and 1978 data, which were developed by interpreting panchromatic aerial photography (Barras et al. 1994; 1:24,000) and color infrared aerial photography (Hartley et al. 2000; 1:65,000) respectively, are based on habitat data that were prepared by the USGS National Wetlands Research Center. The 1965 land-water data consist of panchromatic aerial photographs (Tobin, scale 1:63,000) that were classified using the method described in this report. Land-water data for the recent period of analysis consists of 26 data points from 1983 to 2009. Existing coastal land-water data sets (classified Landsat Thematic Mapper, 25-m; Barras et al. 1994, 2003, 2008; Barras 2006), were supplemented by land-water data developed for regional trend assessments of the deltaic plain (Morton et al. 2005), 2008 hurricane assessments (Barras 2009), and one additional Landsat TM scene from 2009. All land-water classified data were resampled and analyzed at a spatial resolution of 25 m.

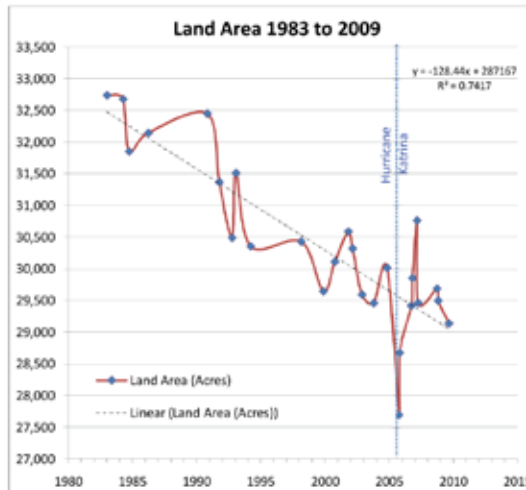
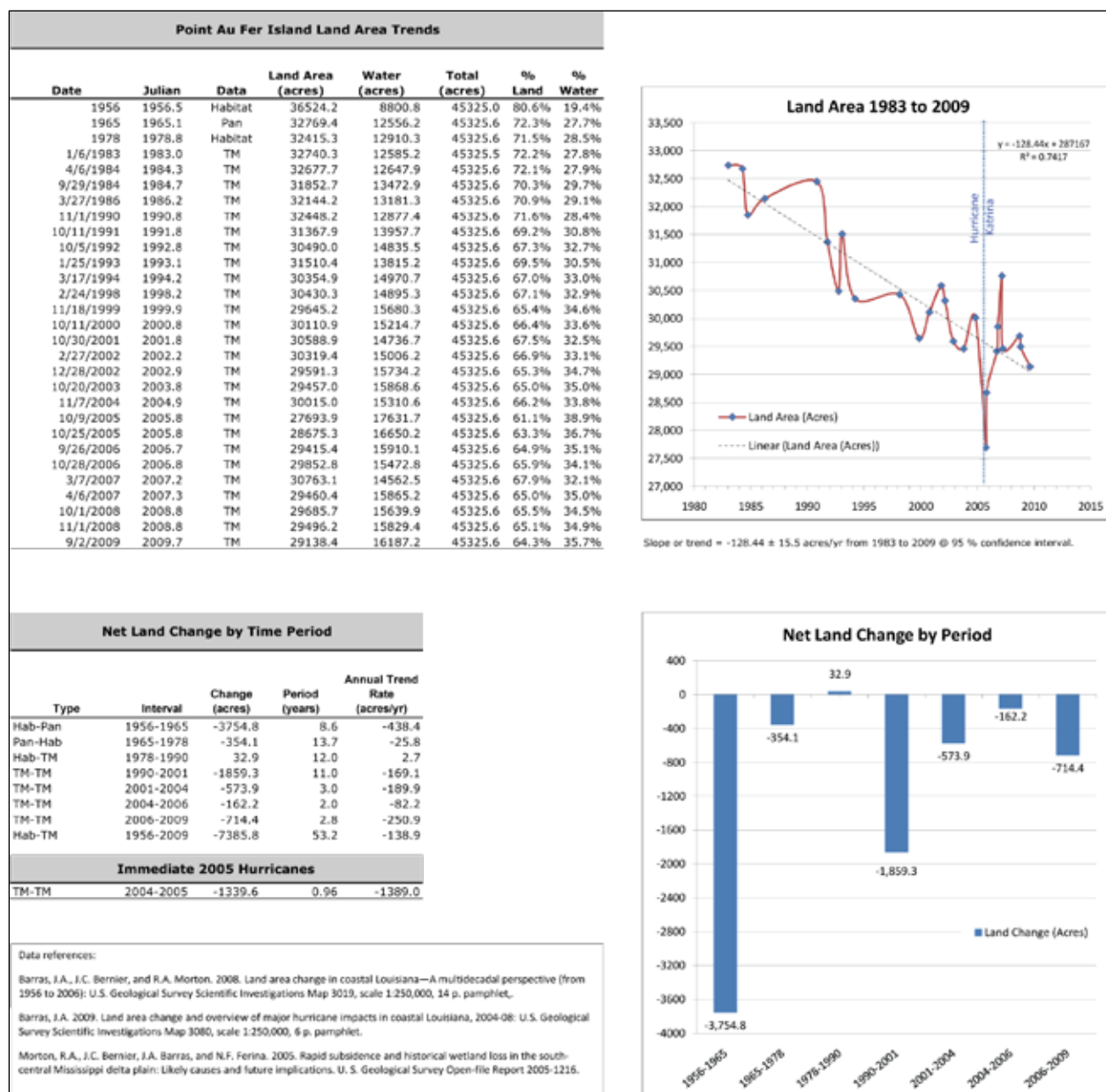
In addition to land area change, a linear regression analysis provides a robust estimate of recent trends by comparing land area over time. Since classified imagery is typically acquired under varying tidal and meteorological conditions, using all available higher temporal frequency data sets (1983-2009) provides a means of reducing short-term variance in land area measurements. Conversely, calculating net trends using only two data points may skew annualized loss rates. For example, a comparison period based on a start date using a classified low water level image compared to an end date based on a high water level image will result in a greater loss estimate for the period and higher projected loss rates. In the case of land change rates, high coefficient of determination (r^2) values indicate constant land area decrease with time, implying that the loss rate may be suitable for short-term future projections. A low r^2 value indicates that either the area has remained stable over the period of analysis, or the loss is not constant with time and may be related to episodic events or other non-linear events.

A.4 Results

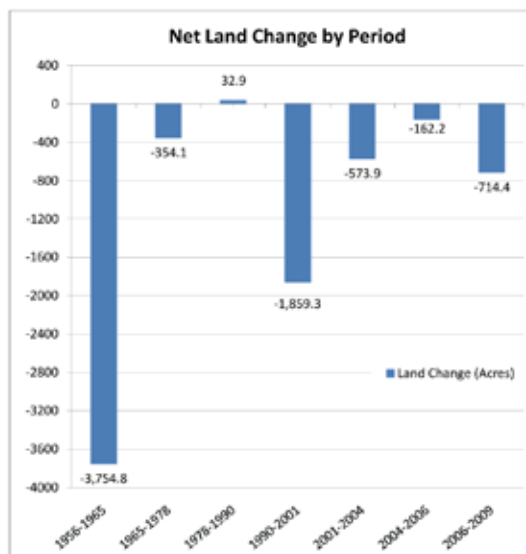
A.4.1 Land change assessments

Table A1 summarizes land-water area and change trends, and Figure A2 illustrates the locations and distribution of the changes that occurred within the PAFI bounding area from 1956 to 2009. In 1956, the project area consisted of approximately 36,524 acres (80.6 % of the project area) of land,

Table A1. Point Au Fer Island Net Land Area and Change Trends.



Slope or trend = -128.44 ± 15.5 acres/yr from 1983 to 2009 @ 95 % confidence interval.



while in 2009 that area was reduced to approximately 29,138 acres (64.3 %). During this 53-year period of analysis, more than 7,385 acres (11.5 square miles) of land was lost. Examining net loss by period for the PAFI project area provides a better understanding of the timing and magnitude of historical and recent land area changes (Table A1). Over the 53-year period of analysis, the assessment interval that accounted for the largest percentage of land area change on PAFI was the 1956-1965 period (Figure A3). Of the 7,385 total acres lost, approximately half was lost during the 1956-1965 historical period. The primary cause of this loss was

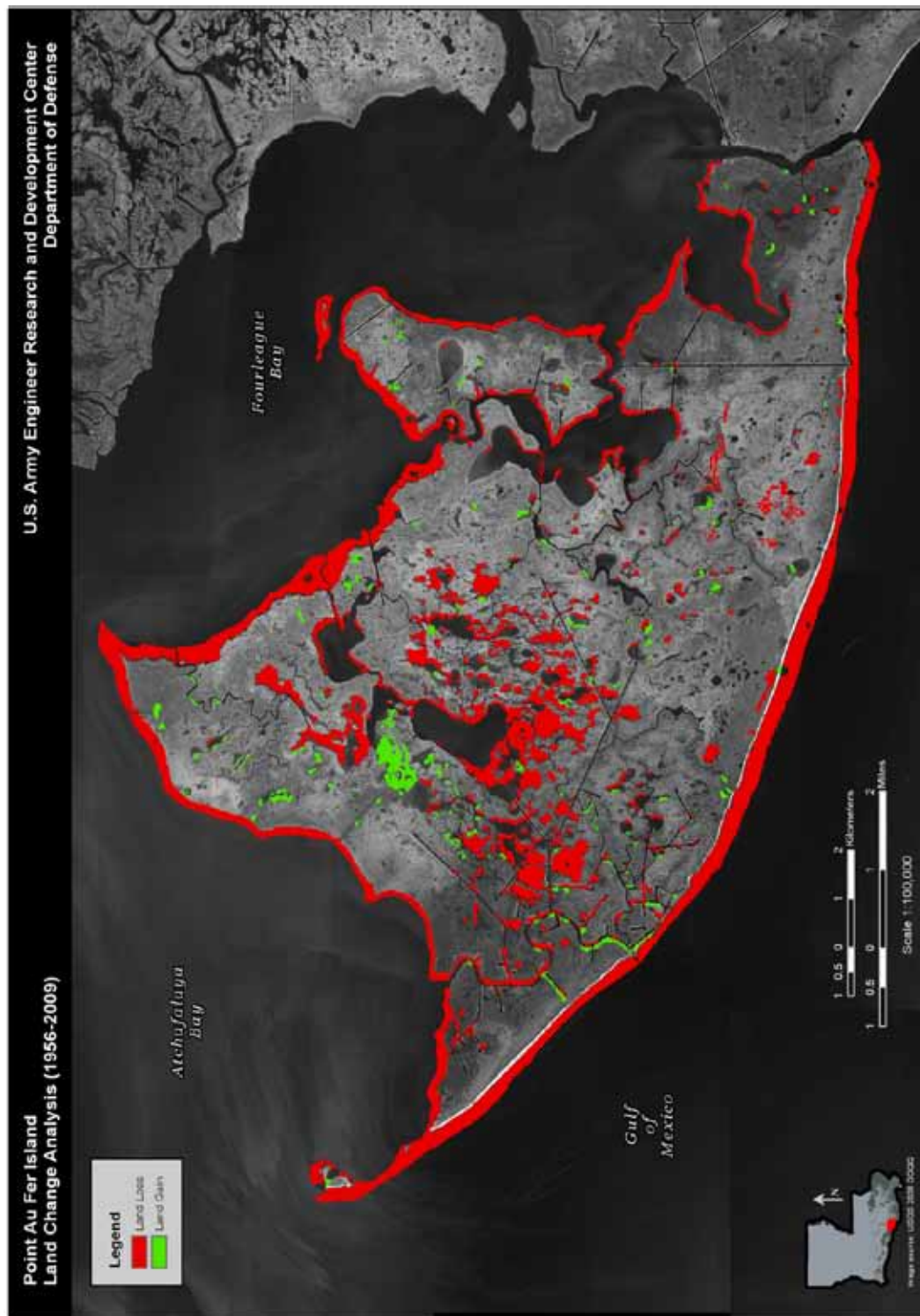


Figure A2. Net land change on Point Au Fer Island, Louisiana for the period of 1956 to 2009.

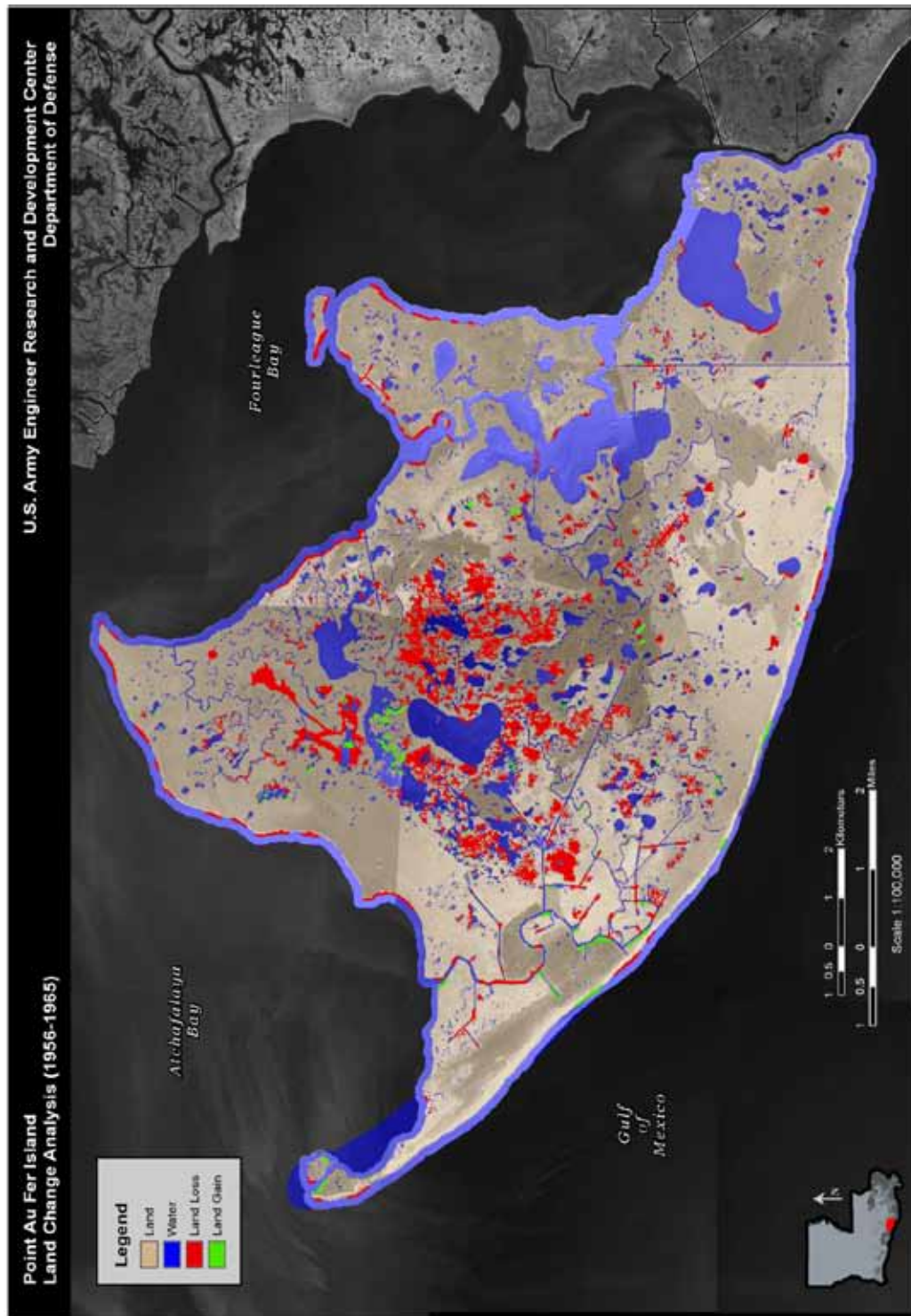


Figure A3. Land change assessment for Point Au Fer Island, Louisiana from 1956 to 1965.

Hurricane Hilda, a Category 2 subtropical cyclone that made landfall on October 3, 1964. The track of Hurricane Hilda was due south to north, with the eye of the storm passing through East Cote Blanche Bay, placing PAFI within the storm's northeastern quadrant. The 1965 panchromatic photography analyzed for this study, acquired four months after landfall, depicts a landscape with direct storm-induced removal and compression of PAFI interior marsh. Typical storm-formed features include plucked marsh, amorphous ponds, orthogonal-elongate ponds, and braided channels (Morton and Barras, in preparation). The storm-formed features remained in place and retained their original shape for over half a century.

The relationships between storm parameters (size, intensity, and track) and the extent of impacts to coastal landscapes can be ambiguous. An example of this is Hurricane Carmen, a Category 3 storm whose eye tracked southeast to northwest on September 8, 1974, making landfall on PAFI. Though PAFI was in the direct path of Hurricane Carmen, the 1965-1978 period only accounts for -4.7 % of the 1956-2009 total land loss. These losses may have been offset by the redistribution of sediment into, and/or the vegetation colonization of shallow ponds and previously denuded marsh (Figure A4). The 1978-1990 assessment interval was stable with moderate land change, accounting for +0.4 % of the total land change that occurred on PAFI (Table A1 and Figure A5). The 1990-2001 period incurred the second greatest amount of land loss (Figure A6). This loss, 1,859 acres (25 % of the total land loss), was due primarily to the direct impacts of Hurricane Andrew. Hurricane Andrew, which made landfall on August 26, 1992, was a Category 4 storm that also tracked to the immediate west of PAFI. The final assessment interval, 2001-2009, accounted for more than 1,450 acres of land loss (19.6 % of the total loss; Figure A7). The land changes occurring during this period resulted from baseline erosion and direct impacts from Hurricanes Lili (Category 1 storm, October 3, 2002) Rita (Category 3 storm, September 24, 2005), and Gustav (Category 2 storm, September 1, 2008).

Recent land area trends (1983-2009) were calculated for PAFI using 26 classified Landsat TM land-water images and simple linear regression. Data sets containing outlying high and low water levels, and partial cloud cover were excluded from the linear regression trend analysis. The land area change rate for PAFI is -128.4 ± 15.5 acres/yr ($r^2 = 0.74$; Table A1). The moderate to high r^2 value indicates that loss has been relatively constant with time over the past 26 years.

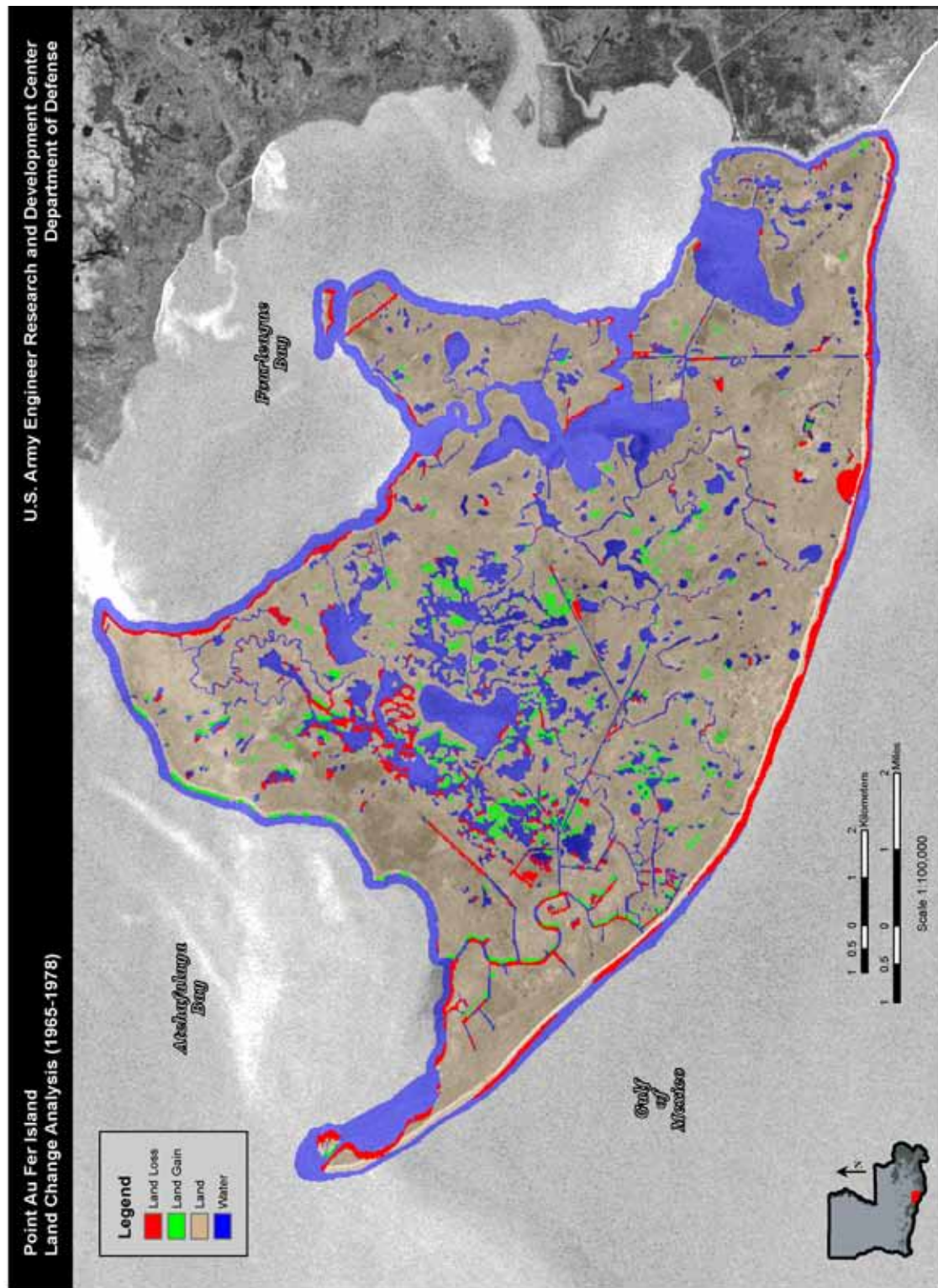


Figure A4. Land change assessment for Point Au Fer Island, Louisiana from 1965 to 1978.

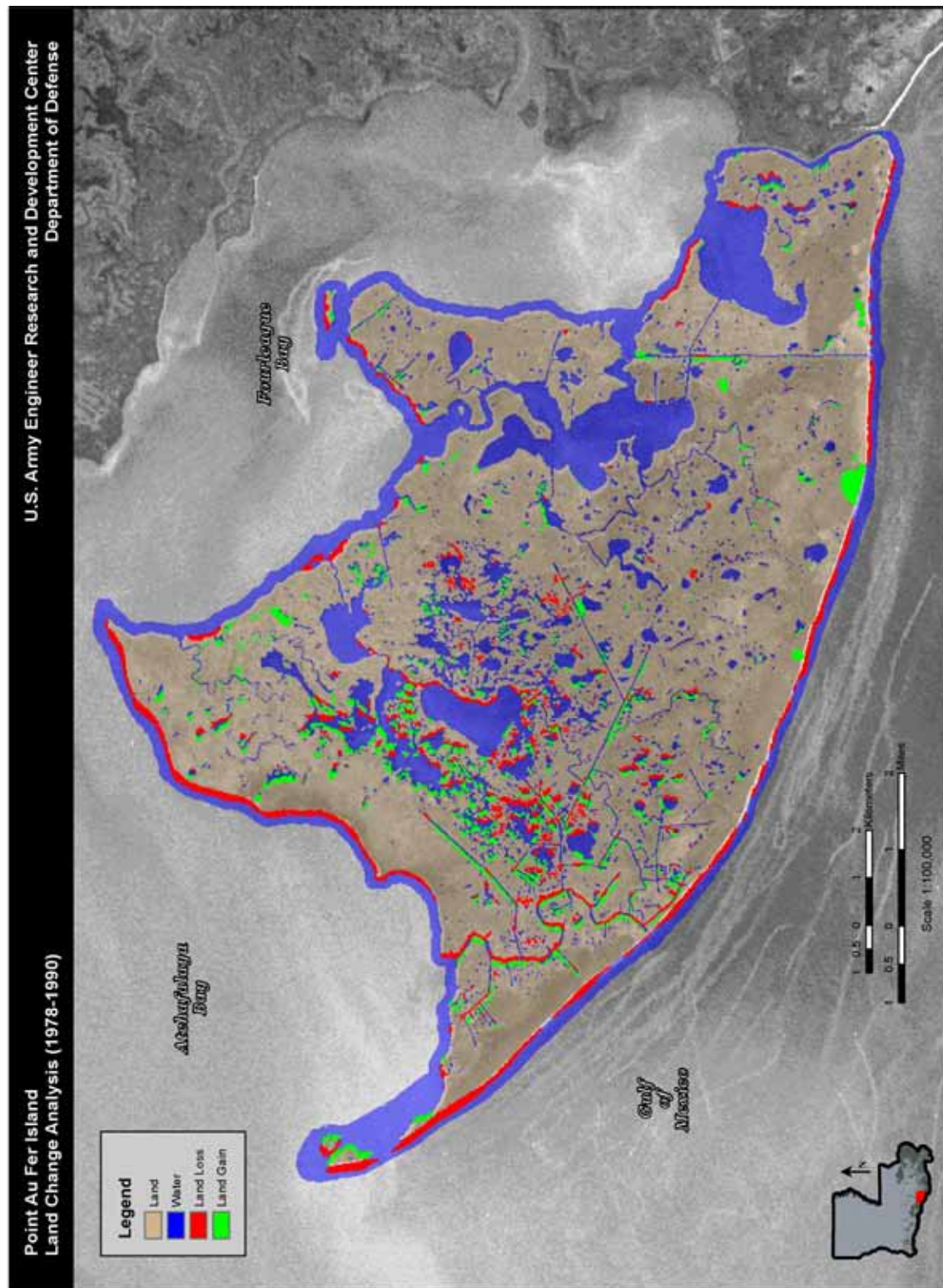


Figure A5. Land change assessment for Point Au Fer Island, Louisiana from 1978 to 1990.

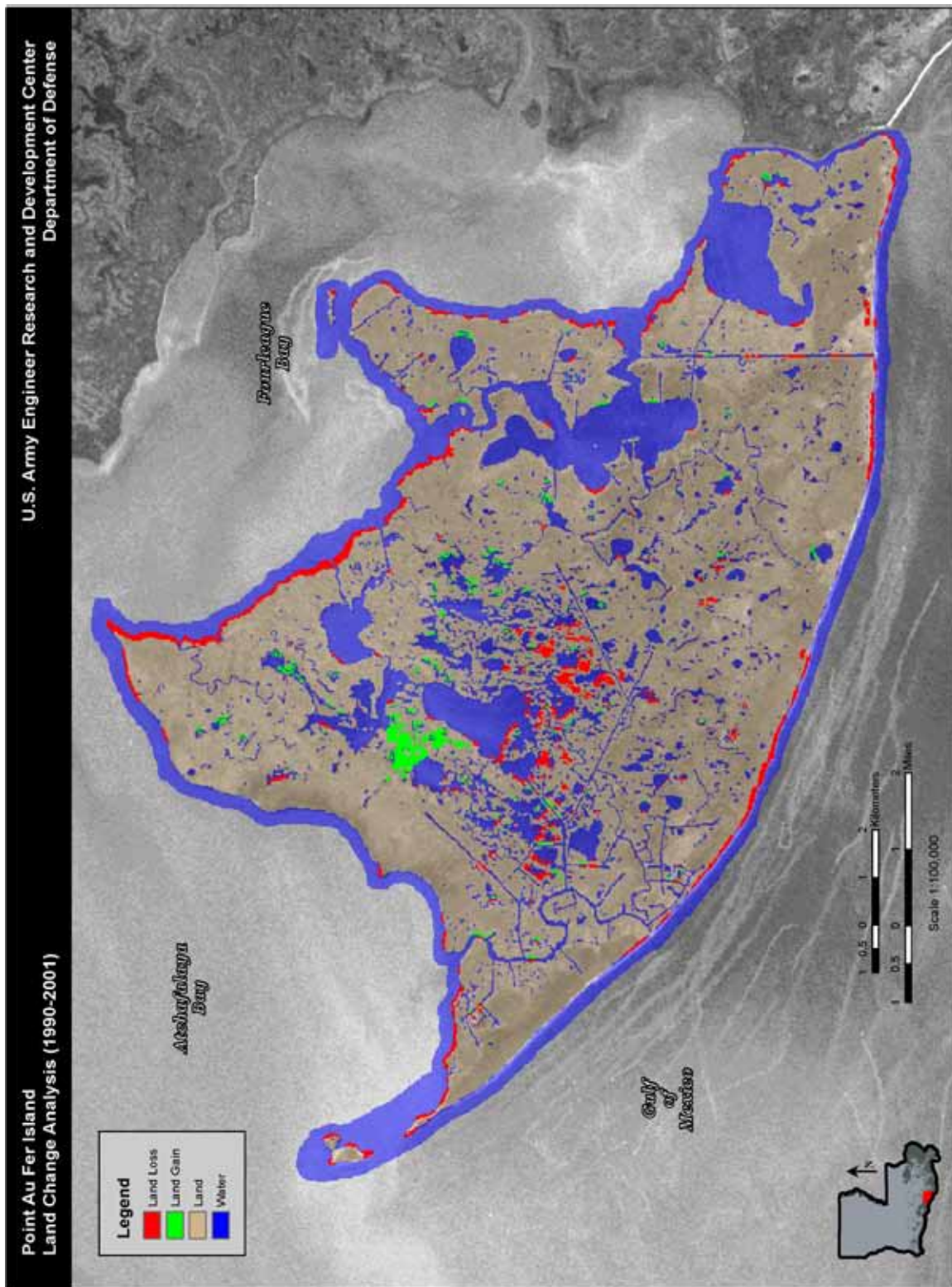


Figure A6. Land change assessment for Point Au Fer Island, Louisiana from 1990 to 2001.

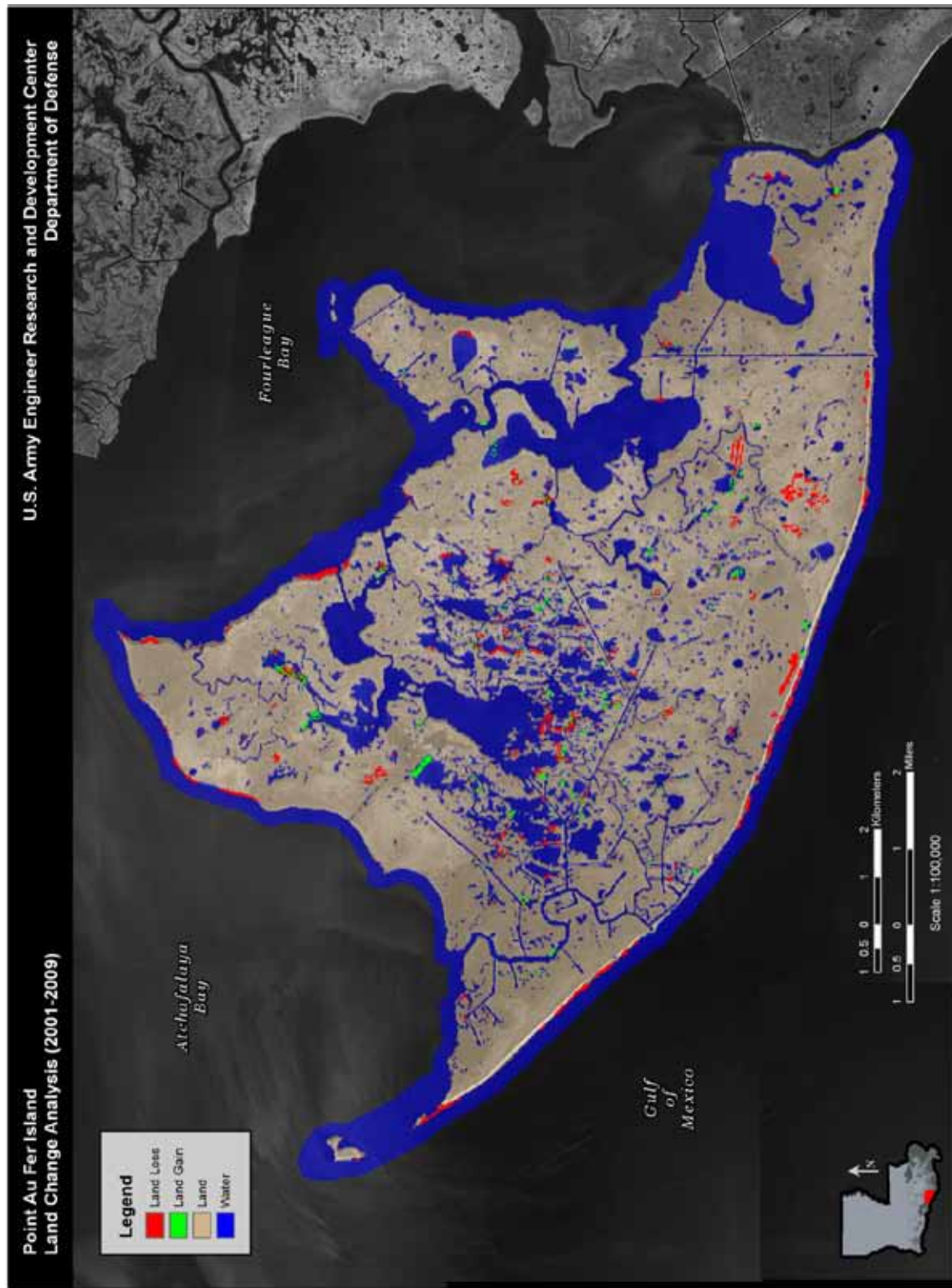


Figure A7. Land change assessment for Point Au Fer Island, Louisiana from 2001 to 2009.

A.4.2 Habitat assessments

Habitat classification and change within the PAFI project area were assessed using data from 1956, 1978, 1988, 2000, and 2006. These data consist of NWI habitat data (1956, 1978, and 1988), and two Landsat TM and coastal marsh vegetation type data composites (2000 and 2006; Figure A8). Habitat data were used to analyze the PAFI project area for habitat switching, which serves as an indicator of sediment, nutrient, or flooding stress. In 1956, the PAFI landscape was predominantly non-fresh marsh (37,491 acres), with nominal amounts of shrub/scrub, inert, beach, and developed habitat types. By 1978, 9,485 acres of brackish marsh had converted to saline marsh or shallow open-water features. These changes resulted from saltwater intrusion, hydrologic alterations, and direct hurricane impacts. The 1978 to 1988 period shows switching patterns between brackish marsh and intermediate marsh in the north-central portion of the island, and an expansion of the saline zone in the southeastern portion of the island. These changes can be attributed to riverine influences from the north, and hydrologic alterations due to oil and gas location canals in the south. The 2000 and 2006 habitat data show that the intermediate zone that was present in 1988 transitioned back to brackish marsh, and by 2006 the area surrounding the location canals at the western end of the island converted to saline marsh. Overall, with the exception of direct conversion to water features (7,036 acres), the switching from brackish to saline communities (6,499 acres), and the Lake Chapeau marsh creation project (large land gain area visible in Figure A2), the habitat on PAFI has remained relatively unchanged.

A.4.3 Shoreline change assessments

A bay- and gulf-side shoreline change analysis was performed for multiple time periods. This assessment was performed by digitizing shorelines using project land-water data, and then calculating period-wise change rates by dividing the area of change by shoreline length, and normalizing by year. Respectively, Tables A2 and A3 summarize bay- and gulf-side shoreline change, area of change (square feet and acres), length of shoreline, and the rates of change from 1965-2009. Island-wide, significant shoreline erosion was experienced over the 1965-2009 period of analysis (ranging from -4.6 to -23.3 ft/year). However, only nominal shoreline change occurred during the 1956-1965 time period (Figure A3). Overall, the bay-side rates of shoreline change were considerably lower than those along the gulfside. These bay-side loss rates ranged from a low of -4.6 ft/year during the

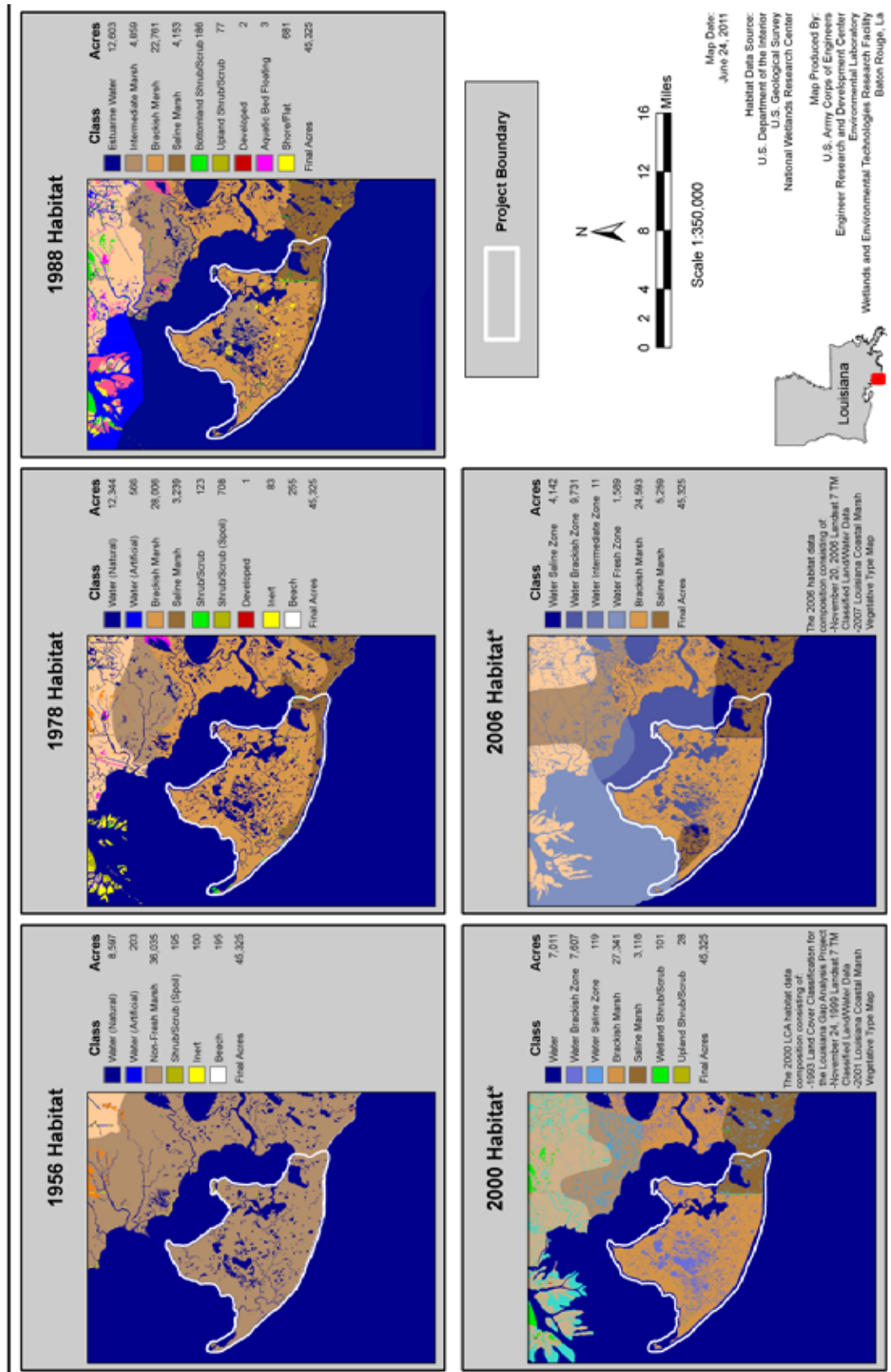


Figure A8. Habitat analysis in the Point Au Fer Island Project Area for years 1956, 1978, 1988, 2000, and 2006.

Table A2. Point Au Fer Island bay-side shoreline erosion rates.

Interval	Area (ft ²) [ac]	Length (ft)	Change (ft/yr)
1965 [†] -1978 [†]	8,073,072 [185]	135,314	-4.6
1978-1990 [‡]	17,935,368 [412]	133,525	-11.2
1990-2001 [‡]	20,000,703 [459]	133,520	-13.6
2001-2009 [‡]	14,612,007 [335]	132,523	-13.8
1965 [†] -2009 [‡]	60,621,149 [1,392]	133,525	-10.3

[†] Shoreline digitized using panchromatic photography resampled to 25-m.

[‡] Shoreline digitized using 25-m Landsat Thematic Mapper imagery.

Table A3. Point Au Fer Island Gulf-side shoreline erosion rates.

Interval	Area (ft ²) [ac]	Length (ft)	Change (ft/yr)
1965 [†] -1978 [†]	25,503,049 [585]	89,951	-21.8
1978-1990 [‡]	25,197,660 [578]	90,078	-23.3
1990-2001 [‡]	13,406,055 [308]	89,428	-13.6
2001-2009 [‡]	11,647,121 [267]	81,205	-17.9
1965 [†] -2009 [‡]	75,753,885 [1,739]	88,235	-19.5

[†] Shoreline digitized using panchromatic photography resampled to 25 m.

[‡] Shoreline digitized using 25-m Landsat Thematic Mapper imagery.

1965-1978 time period, to -13.8 ft/year during the 2001-2009 period, with an overall loss rate of -10.3 ft/year during the 1965-2009 period of analysis. The Gulf-side loss rates ranged from -13.6 ft/year during the 1990-2001 period, to -23.3 ft/year during the 1978-1990 period, with an overall loss rate of -19.6 ft/year during the 1965-2009 period. Approximately 86 % (3,131 of 3,631 acres) of all land lost within the project area during the 1965-2009 period was a result of shoreline erosion (Tables A1, A2, and A3). This land loss (3,131 acres), coupled with the hurricane-induced loss (3,755 acres) that occurred during the 1956-1965 time period, accounts for 93 % of the 1956-2009 total land loss (7,386 acres).

Hurricanes and other extreme extratropical storms have been shown to contribute to extensive shoreline erosion and breaching, and the scouring, compression, and inundation of inland and back-bay wetlands (Meeder 1987, Morton and Sallenger 2003). However, the lower Gulf-side loss rates experienced during assessment periods with high hurricane-induced inland loss rates (1956-1965, 1990-2001, and 2001-2009; Table A3), indicate that natural or baseline conditions may have greater influence on

PAFI Gulf-side shoreline erosion. It should be noted that higher resolution data are typically used to quantify changes along Louisiana's shoreline. However, due to data availability, the moderate resolution land-water images were used. Comparisons between rates calculated using moderate land-water data to those of available higher-resolution data showed no significant differences.

A.4.4 Soil assessments

PAFI consists of eight soil types: six mucks (Banker, Bellpass, Clovelly, Lafitte, Scatlake, and Timbalier), one loamy fine sand (Felicity), and one dredged soil (Aquents) (Table A4). Figure A9 illustrates the distribution and extent of these soil types. With few exceptions, these soils exist in brackish to saline landscapes and are not conducive to any use except marsh and swamp habitat. Table A4 shows that of the 7,385.9 acres that were lost during the 1956-2009 period, 34.5, 20.3, and 19.7 % were lost in Lafitte, Clovelly, and Felicity soils, respectively. The majority of interior island land loss occurred during the 1956-1965 time period, and almost exclusively coincides with the Lafitte muck. The lake-rim, and bay- and Gulf-side shoreline erosion occurred primarily within regions of the Clovelly and Felicity soil types. The remaining five soil types accounted for approximately 25 % of both inland and shoreline land loss.

Overlaying the 1956-2009 land change areas on the soils layer in Figure A9 provides a means of assessing possible correlations between land loss events and soil type. These data, coupled with the soil unit change acreages (Table A4) and the sequence of land loss (Table A1 and Figures A3-A7), serve as indicators of soil stability and resistance to land change drivers. The Lafitte soil appears to be least resistant to hurricane impacts, but relatively narrow swaths of shoreline erosion along the margins of this soil type indicate that it may be more resistant to shoreline erosional forces. The inverse may be true of the other soils, where they appear to be the most stable at the interior of the island, and more prone to erosion along the shorelines.

A.5 Conclusion

The extensive historical landscape analyses and interpretation conducted as part of this study provided a mechanism for testing and utilizing the novel method that was developed to expedite the classification of panchromatic aerial photography. These data and analyses were compiled and disseminated to the USACE New Orleans District and LCA PAFI Project

Delivery Team. These results, which proved to be a critical component of project plan formulation, identified areas of significant hurricane-induced land loss and resulted in the addition of restoration features and expansion of the project area (addition of interior and back-bay marsh restoration measures).

Table A4. Point Au Fer Island soil area and unit change.

Soil Map Unit	1956 Area (acres)	2009 Area (acres)	1956-2009 Loss (acres)	Soil Unit Change (percent)	Project Area Change (percent)
Aquents, dredged	1,196.6	792.0	-404.6	-33.8%	-5.5%
Bancker muck	1,091.6	679.6	-412.0	-37.7%	-5.6%
Bellpass muck	2,345.8	2,121.3	-224.5	-9.6%	-3.0%
Clovelly muck	10,550.5	9,048.8	-1,501.7	-14.2%	-20.3%
Felicity loamy fine sand	1,495.9	40.2	-1,455.7	-97.3%	-19.7%
Lafitte muck	12,929.6	10,382.1	-2,547.5	-19.7%	-34.5%
Scatlake muck	4,664.9	4,110.4	-554.5	-11.9%	-7.5%
Timbalier muck	2,249.3	1,963.9	-285.4	-12.7%	-3.9%
Total	36,524.2	29,138.3	-7,385.9	-	-100.0%

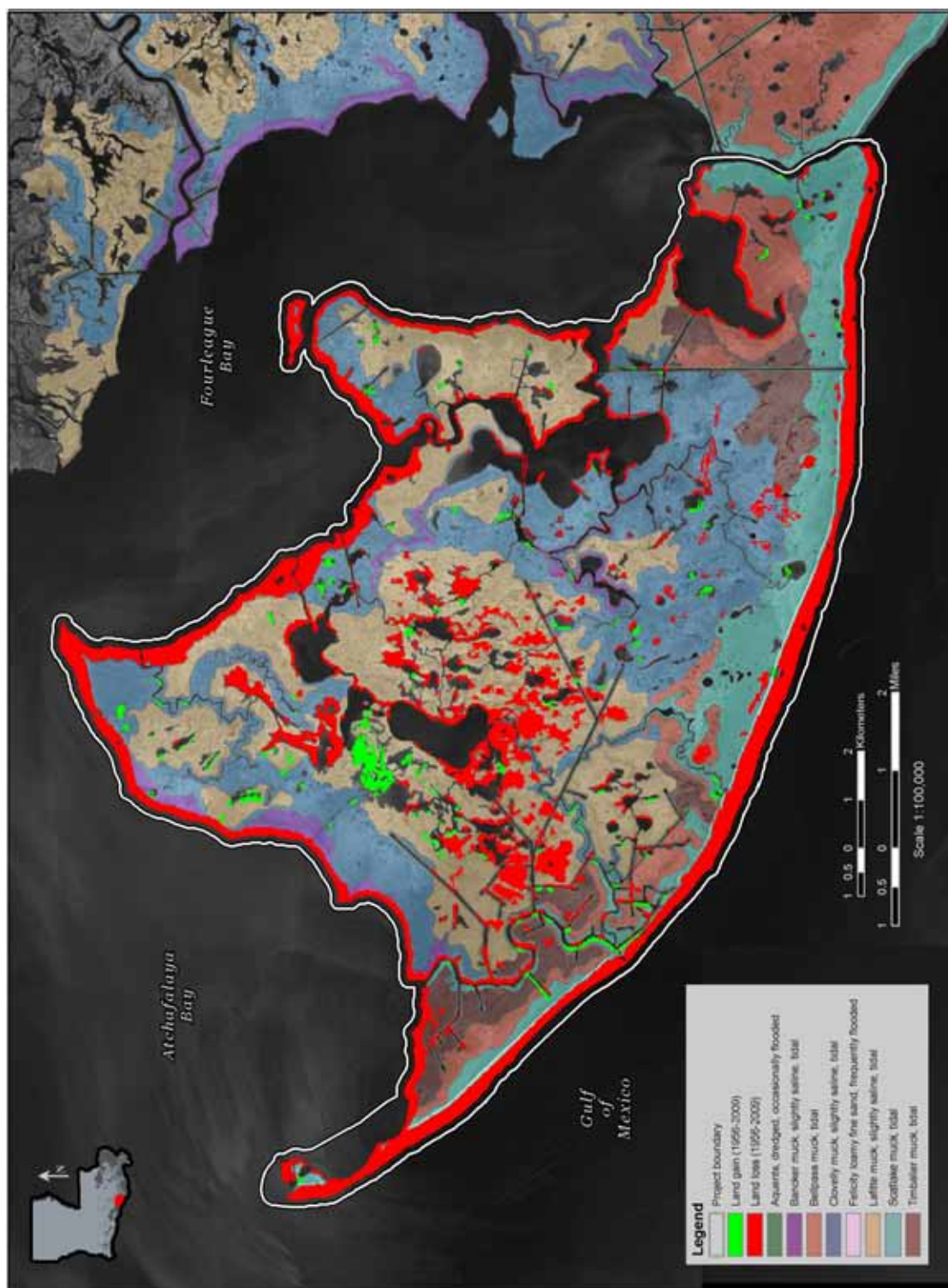


Figure A9. The distribution of soils (Natural Resources Conservation Service, Soil Survey Geographic Database) within the Point Au Fer Island project area, overlaid with net land change (1956-2009).

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14. ABSTRACT Recent studies of coastal Louisiana landscapes have shown an increased connection between historical episodic events and current landscape condition. Therefore, the importance of historical landscape reconstruction through the interpretation of panchromatic aerial photography has increased because it provides synoptic views of hydrology, vegetation, and ecosystems for time periods when data options are limited. Though panchromatic aerial photographs provide a valuable historical record of past landscape conditions, their use is limited in current landscape analyses due to issues with established automated techniques to classify these data (e.g. only one gray level band, and illumination inconsistencies), and the subjectivity and time-intensive nature of human-derived photo-interpretation products. This report documents a method that was developed to improve panchromatic aerial photography classification by increasing accuracy and control and reducing the time-intensive nature of this technique. This method provides a novel approach to selecting landscape features based on a specific range of pixel values (color), contrast, texture, and pattern within a single gray level band of source photography. The resulting techniques were evaluated and used to classify and assess historical land and shoreline change at Point Au Fer Island (PAFI), Louisiana. Assessments show that though this method is more time-intensive than the automated classification approaches used with color-infrared and multispectral data, it provides many advantages over previous panchromatic aerial photography classification methods. These advantages include the use of image level, contrast, and color adjustments; tools to rapidly select features of similar characteristics; and adjustment layers to enhance the visual identification of the land-water features and interface.					
15. SUBJECT TERMS Panchromatic aerial photography Coastal Louisiana Point Au Fer Island (PAFI), Louisiana Historical landscape reconstruction					
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